
# Real-time Air Quality Modeling System aerosol and ozone assimilation and forecasting experiments using A-Train measurements during the NOAA CalNex field mission

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**[2]UW-Madison Space Science and Engineering Center, Madison, WI**
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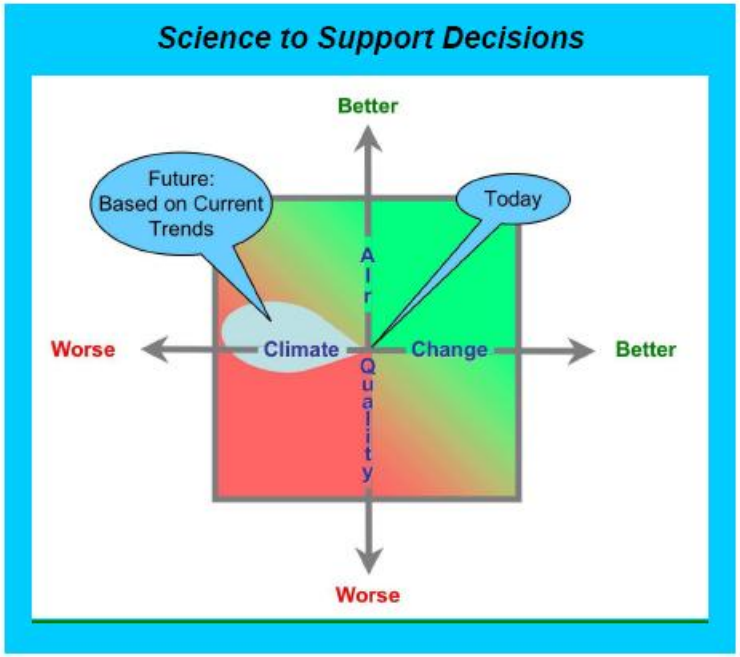
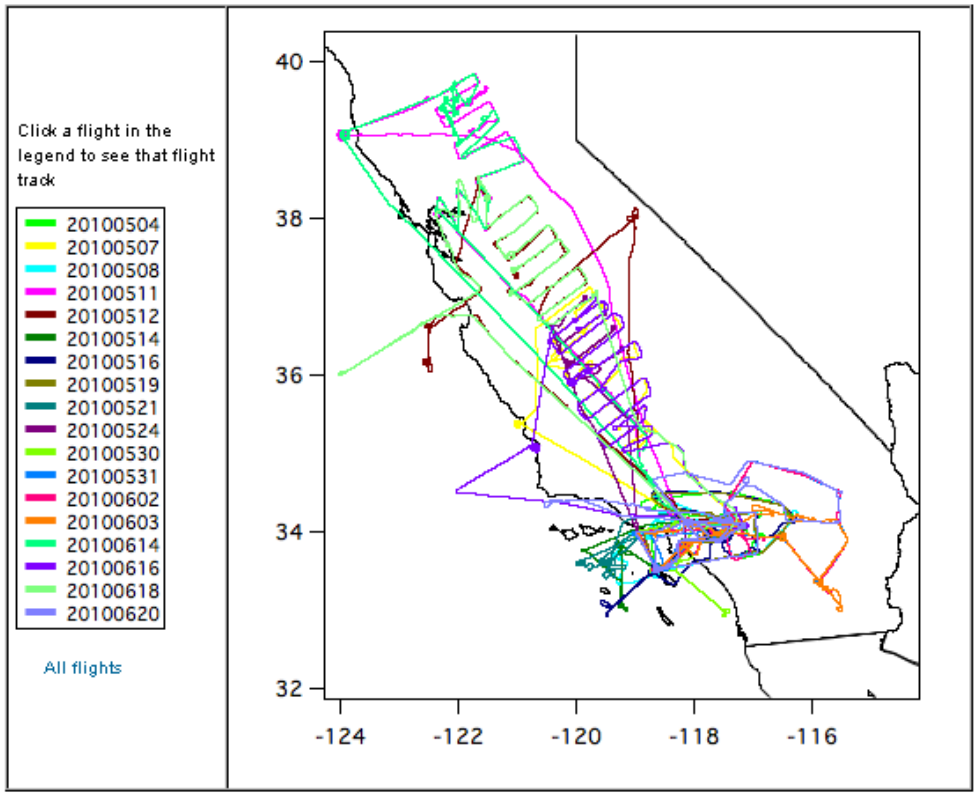
# NOAA CalNex Field Mission

During May-June 2010 the National Oceanic and Atmospheric Administration (NOAA) and the California Air Resources Board (CARB), conducted a joint field study of atmospheric processes over California and the eastern Pacific coastal region called CalNex emphasizing the interactions between air quality and climate change issues.




Research at the Nexus of Air Quality and Climate Change

## NOAA WP-3D Flight Track Map




http://www.esrl.noaa.gov/csd/calnex/

The Real-time Air Quality Modeling System (RAQMS) chemical and aerosol forecasts, initialized with real-time A-Train measurements were used for daily flight planning activities and provided lateral boundary conditions for regional air quality forecasts during CalNex.

# Real-time Air Quality Modeling System (RAQMS)

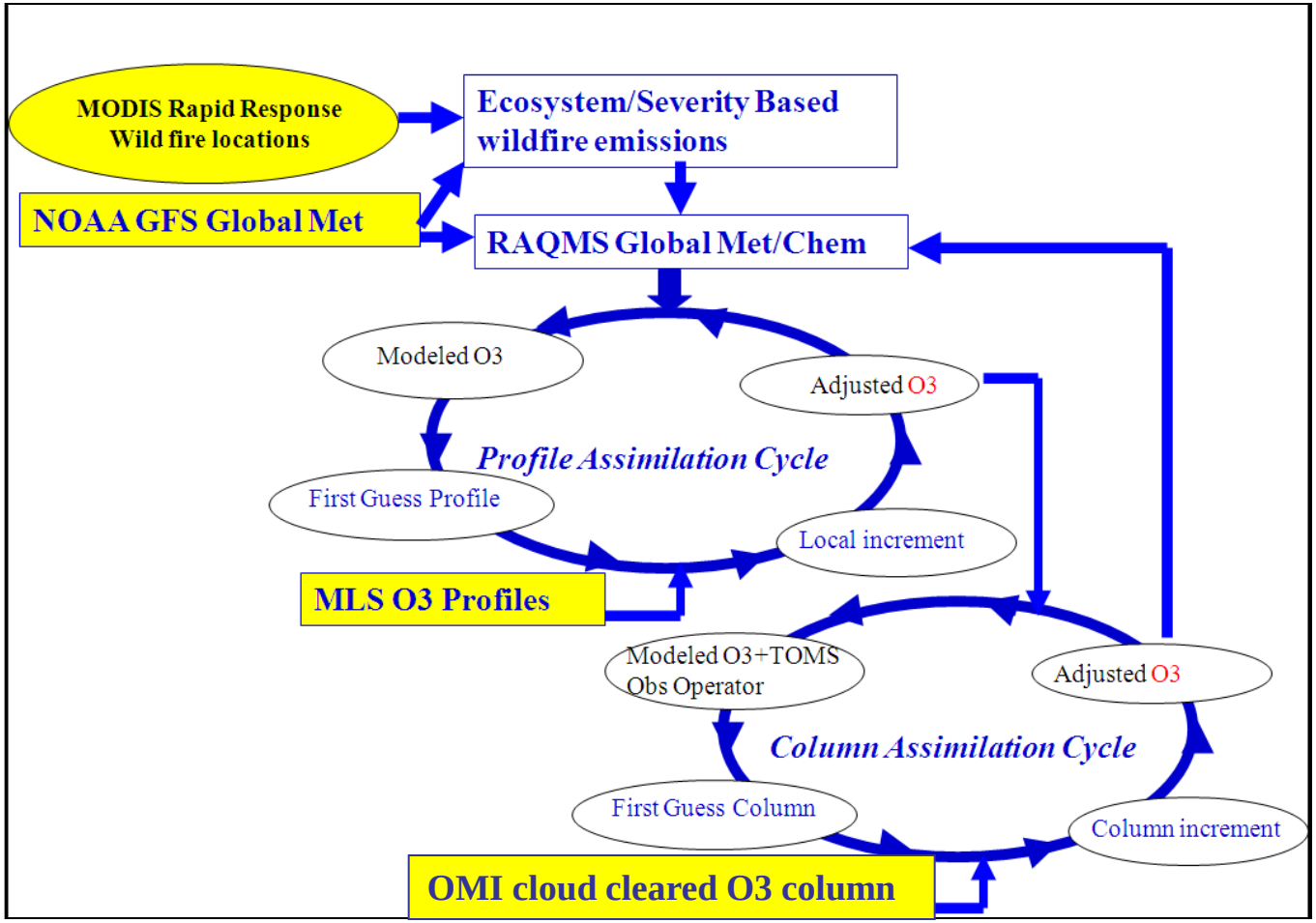
1) **Online global chemical and aerosol assimilation/forecasting system**
2) **UW-Madison sigma-theta hybrid coordinate model (UW-Hybrid) dynamical core**
3) **Unified stratosphere/troposphere chemical prediction scheme (LaRC-Combo) developed at NASA LaRC**
4) **Aerosol prediction scheme (GOCART) developed by Mian Chin (NASA GSFC).**
5) **Statistical Digital Filter assimilation system developed by James Stobie (NASA/GFSC)**

This talk presents results from post mission studies focused on evaluation of the RAQMS large-scale ozone and aerosol analyses and forecast skill.

- Evaluation is based on comparisons with satellite, ground based, and airborne observations.

- Forecast skill is evaluated through analysis of anomaly correlations

# RAQMS CalNex O3 Assimilation Procedure

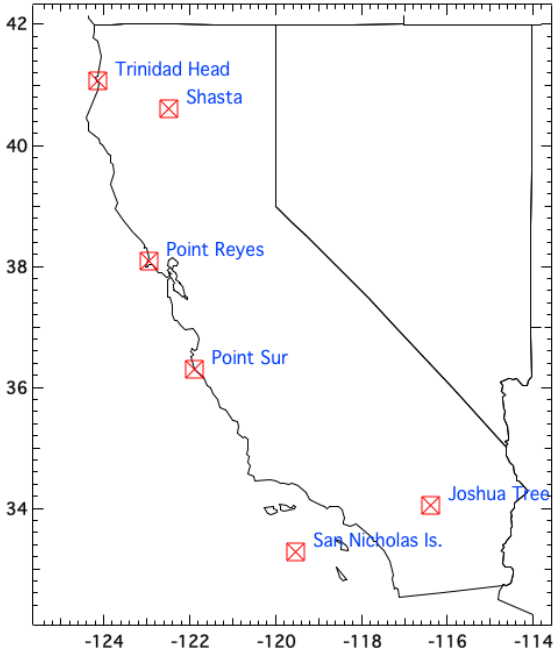


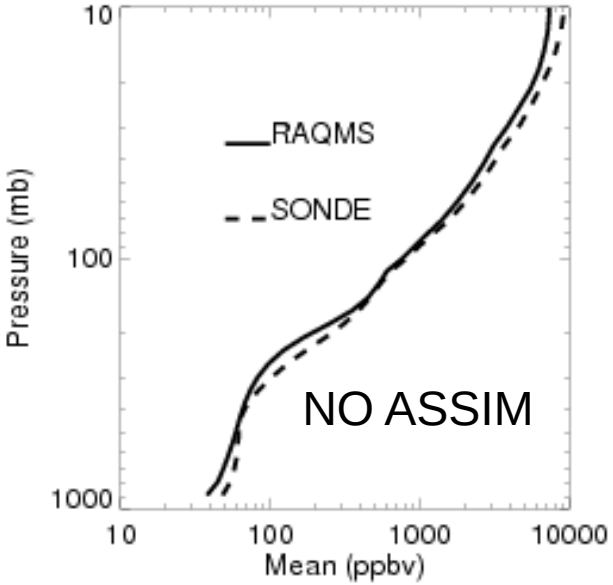

**Demonstration of:**

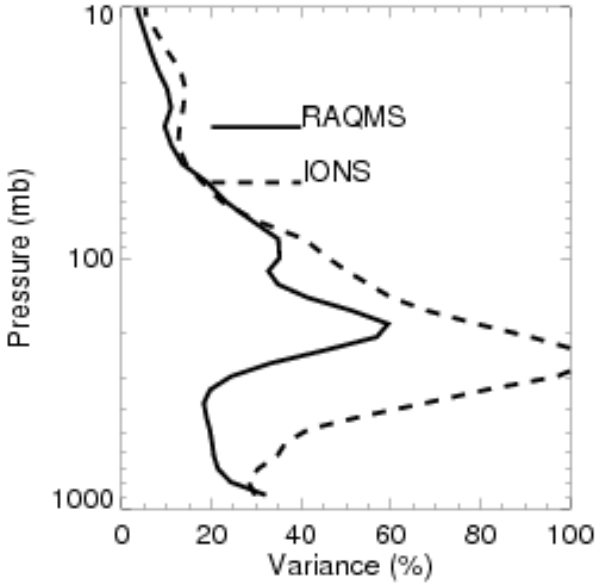
- **Real-time assimilation of Microwave Limb Sounder (MLS) stratospheric ozone profiles**
- **Real-time assimilation of Ozone Monitoring Instrument (OMI) total ozone column**
- **Real-time incorporation of Moderate Resolution Imaging Spectroradiometer (MODIS) fire detection**

# CalNex-2010 $O_3$ sondes – Owen Cooper (NOAA ESRL)

## CalNex Ozonesonde

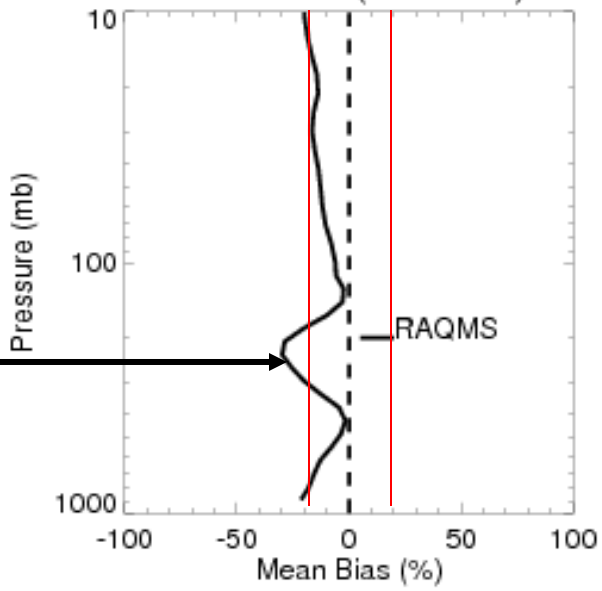


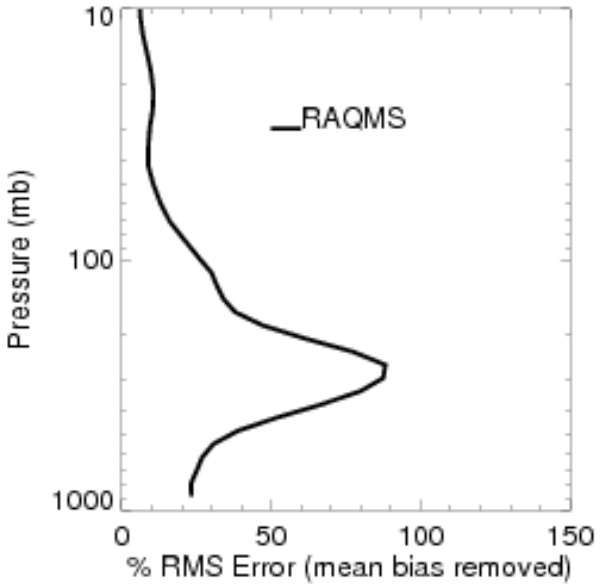




CalNex IONS May-June, 2010 RAQMS NO ASSIM/Sonde O3
(178 sondes)

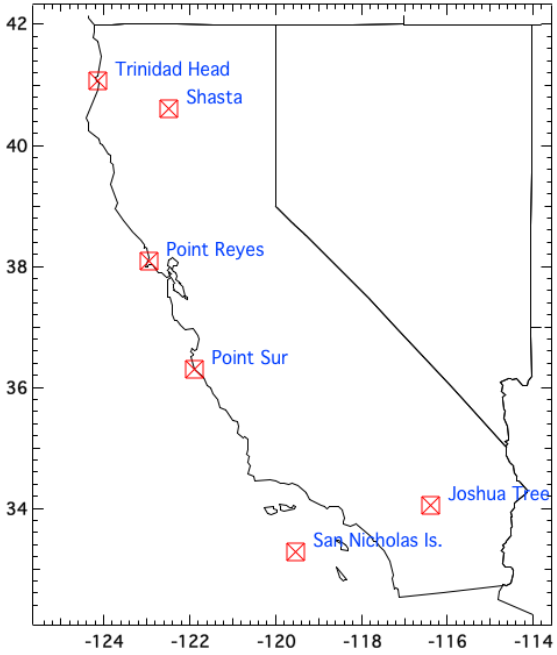
**RAQMS <u>NO ASSIM</u>**
**is low biased up to**
**30% of Ozonesonde**

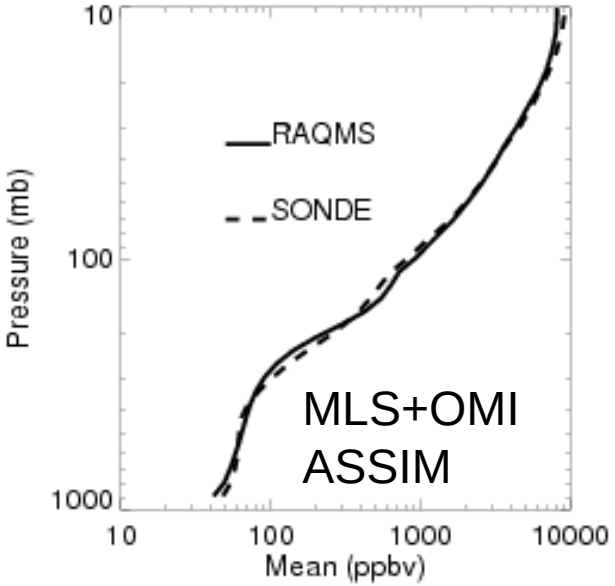


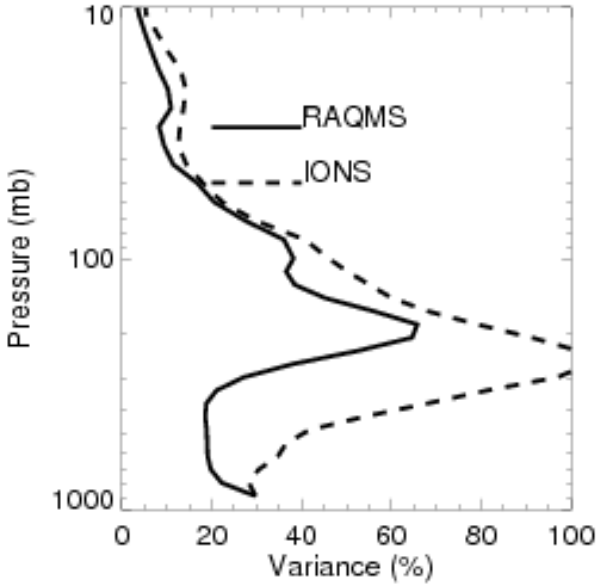



# CalNex-2010 $O_3$ sondes – Owen Cooper (NOAA ESRL)

**CalNex Ozonesonde**

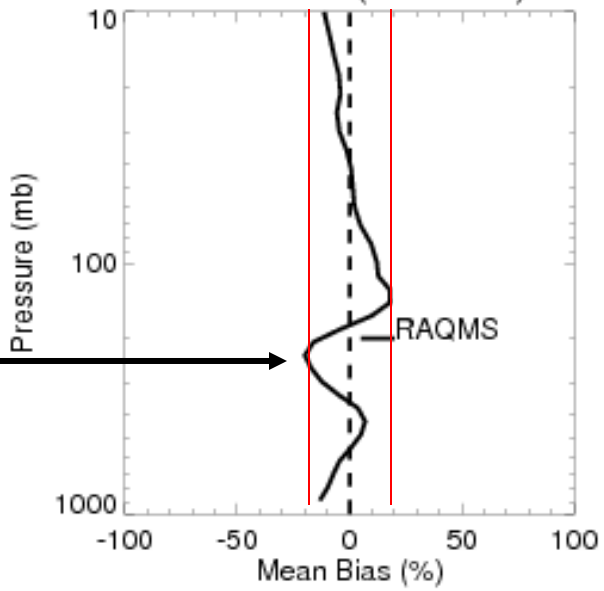


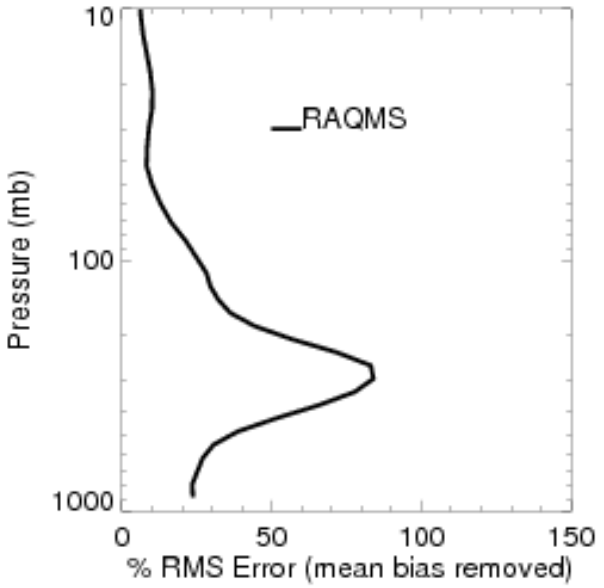



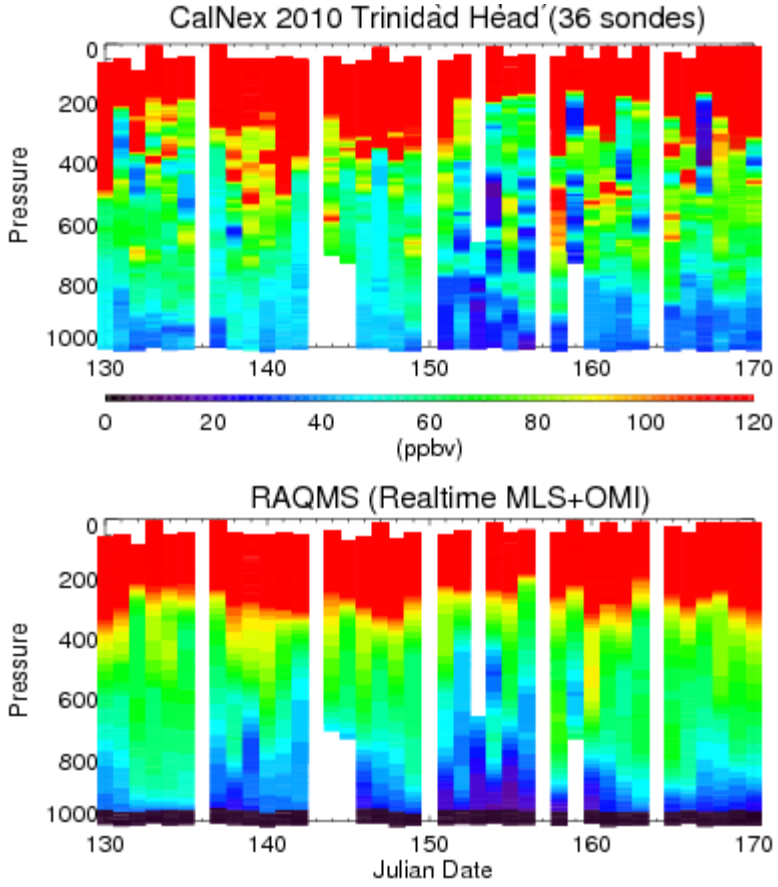

CalNex IONS May-June, 2010 $RAQMS_{Realtime\ MLS+OMI}$/Sonde O3
(178 sondes)

**RAQMS <u>MLS+OMI</u> analysis is within 20% of Ozonesonde**

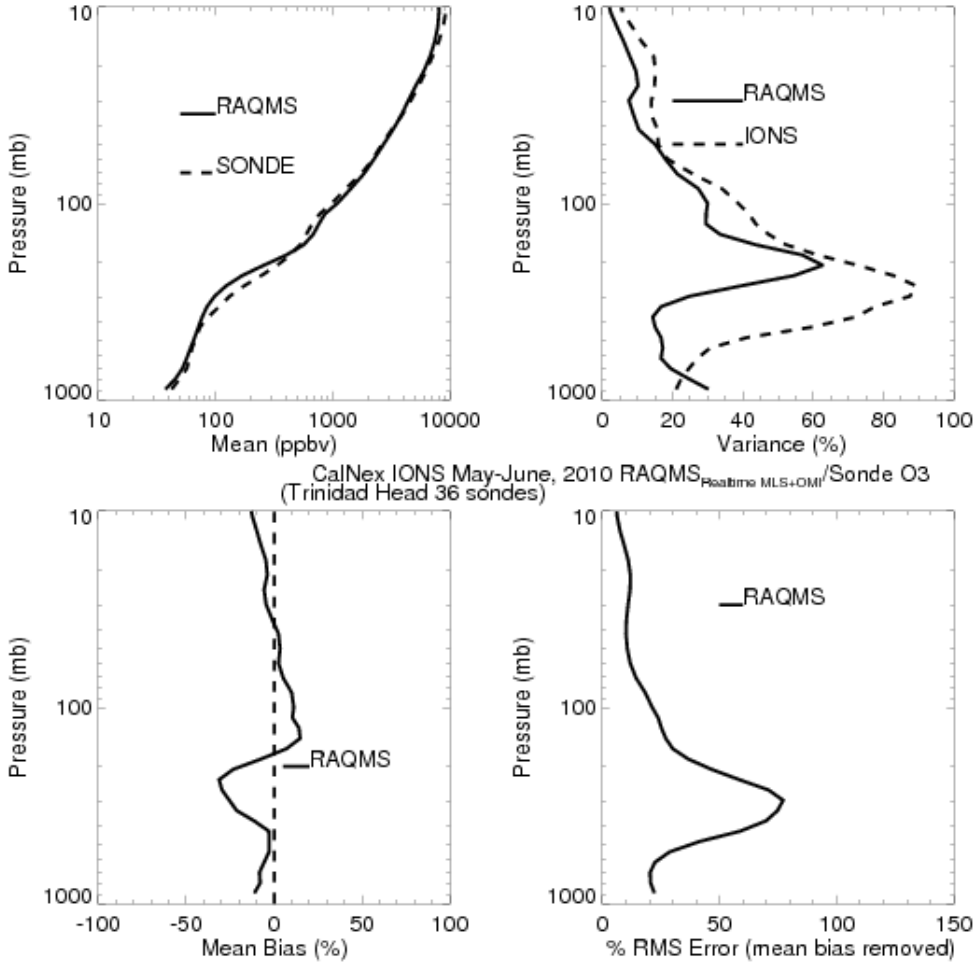


# CalNex-2010 $O_3$ sondes – Owen Cooper (NOAA ESRL)




Assimilation of MLS+OMI O3 retrievals increases lower stratospheric ozone mixing ratios, resulting in increased mid-tropospheric O3 (and improved agreement with background ozonesondes) due to Strat/Trop Exchange (STE)

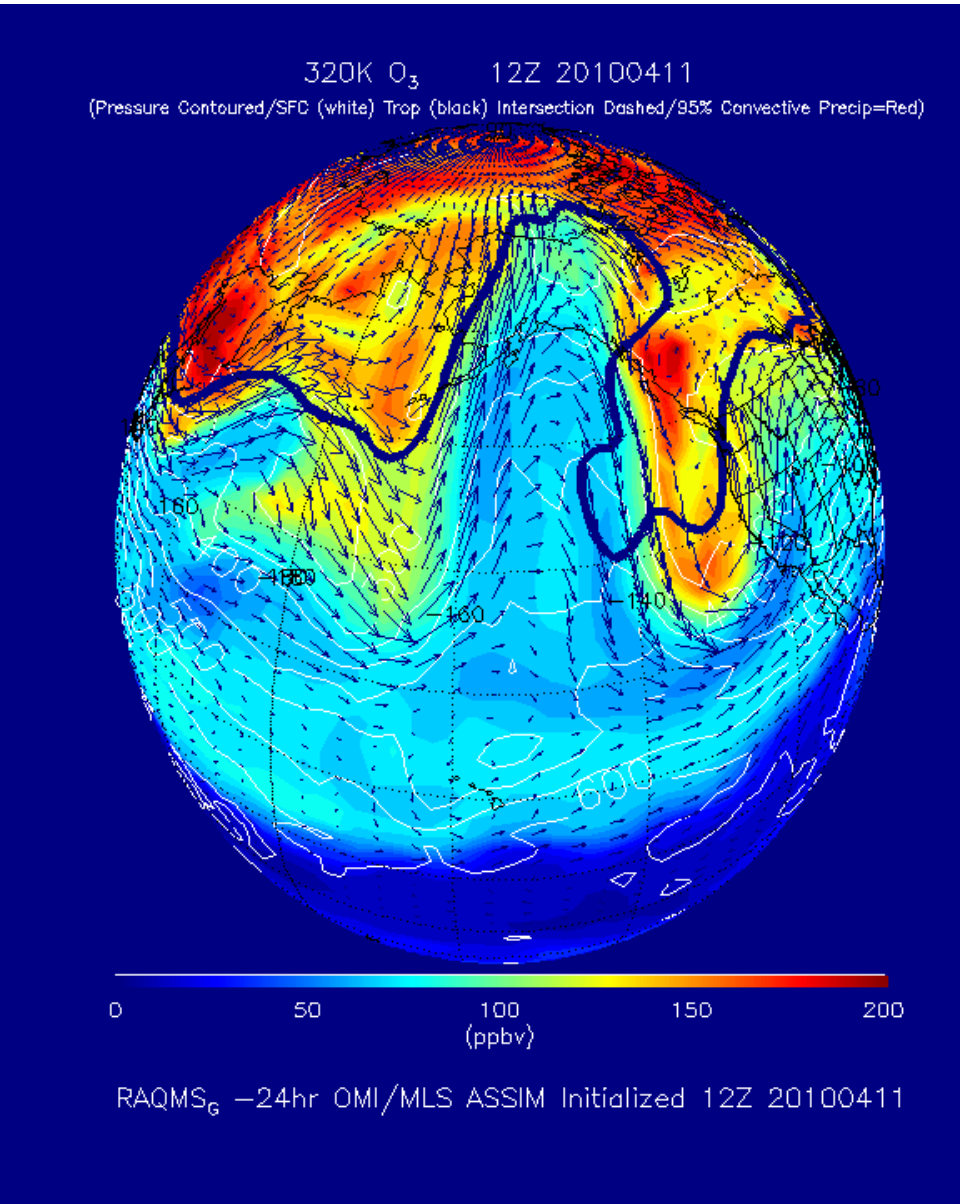


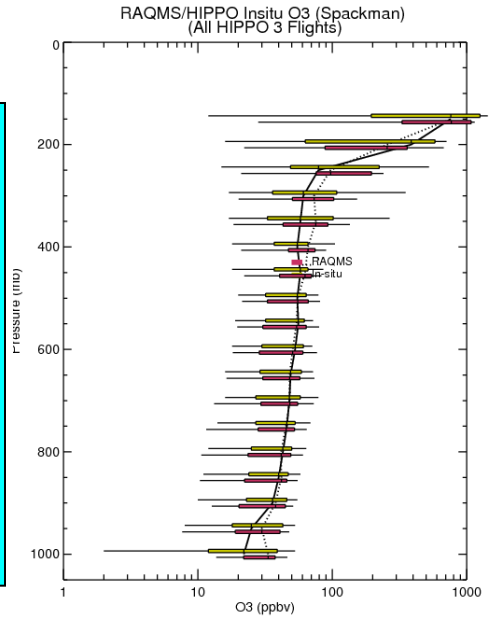

RAQMS 2x2 analysis does not resolve observed narrow ozone lamina with high (>100ppbv) ozone mixing ratios associated with STE which accounts for much of the mid and upper tropospheric variance

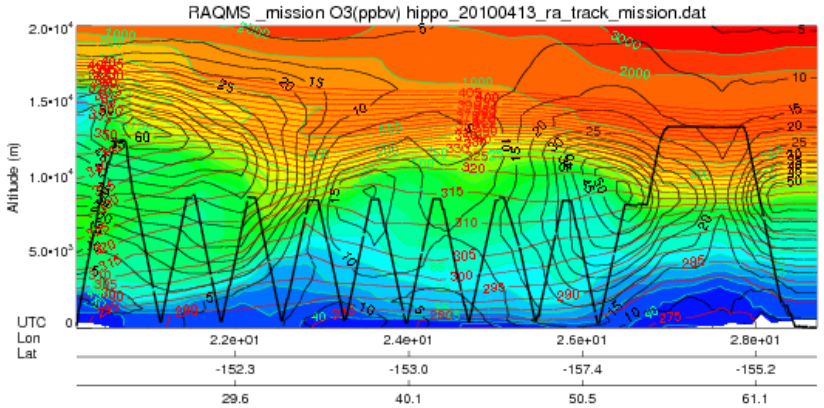
# NSF HIAPER POLE-TO-POLE OBSERVATIONS (HIPPO)

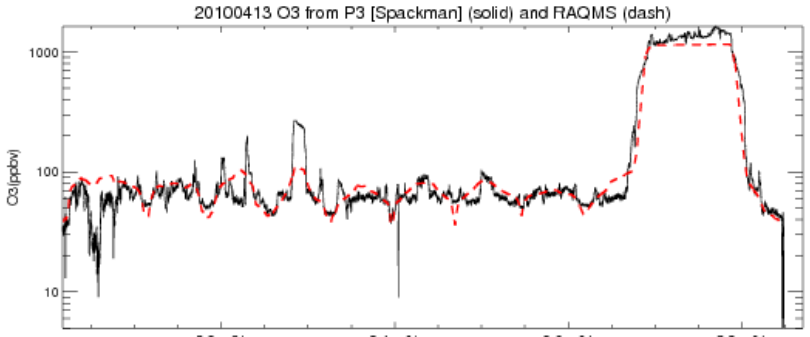
**Timeframe: March-April 2010**
**Mission scientist: Steve Wofsy (Harvard)**
**O3 PI: Ryan Spackman (NOAA/ESRL)**

Illustration of upper and mid tropospheric O3 enhancements during NSF HIAPER flight on 02/13 2010 due to STE

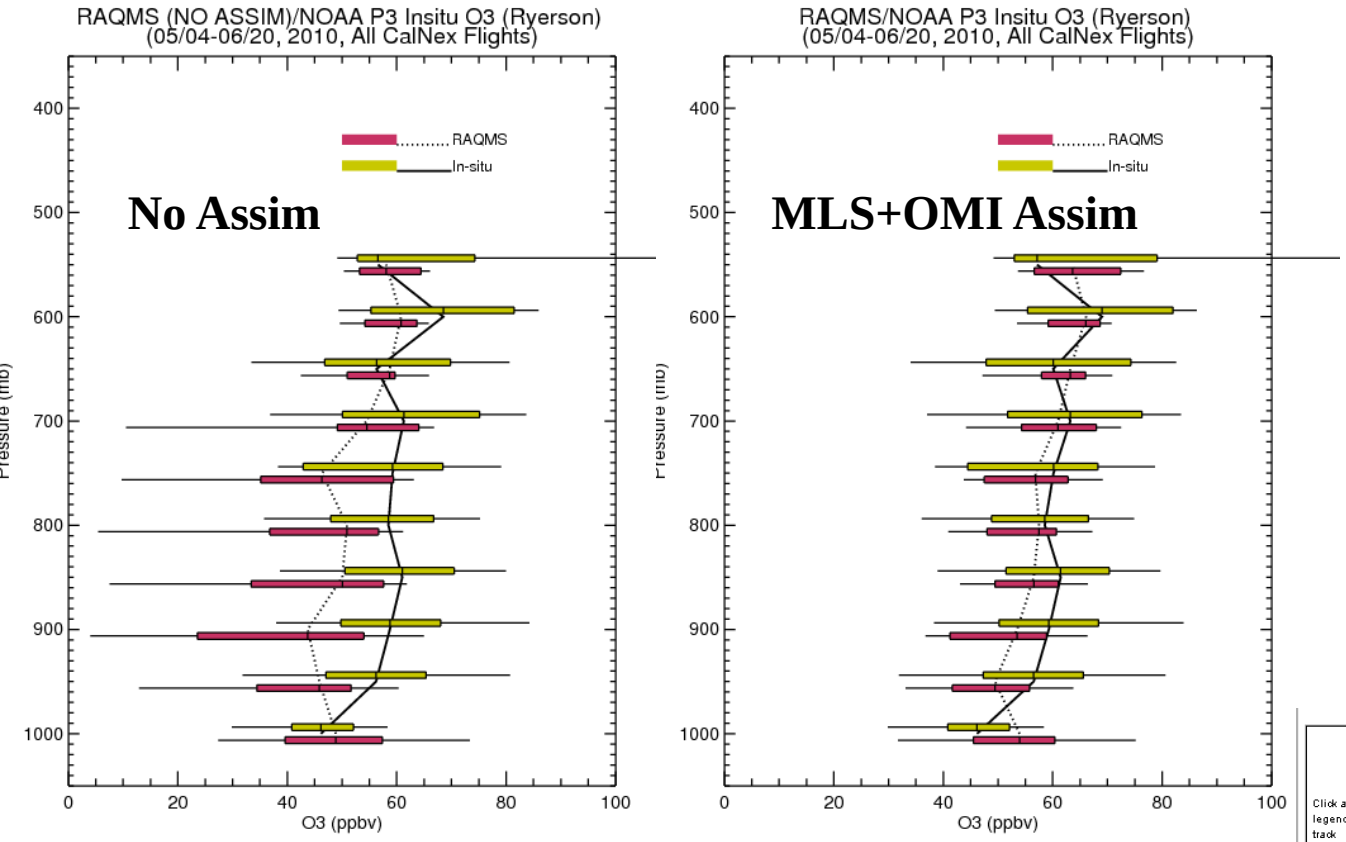


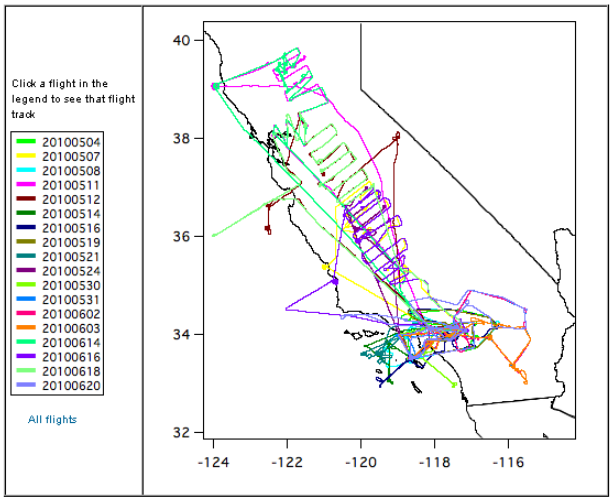



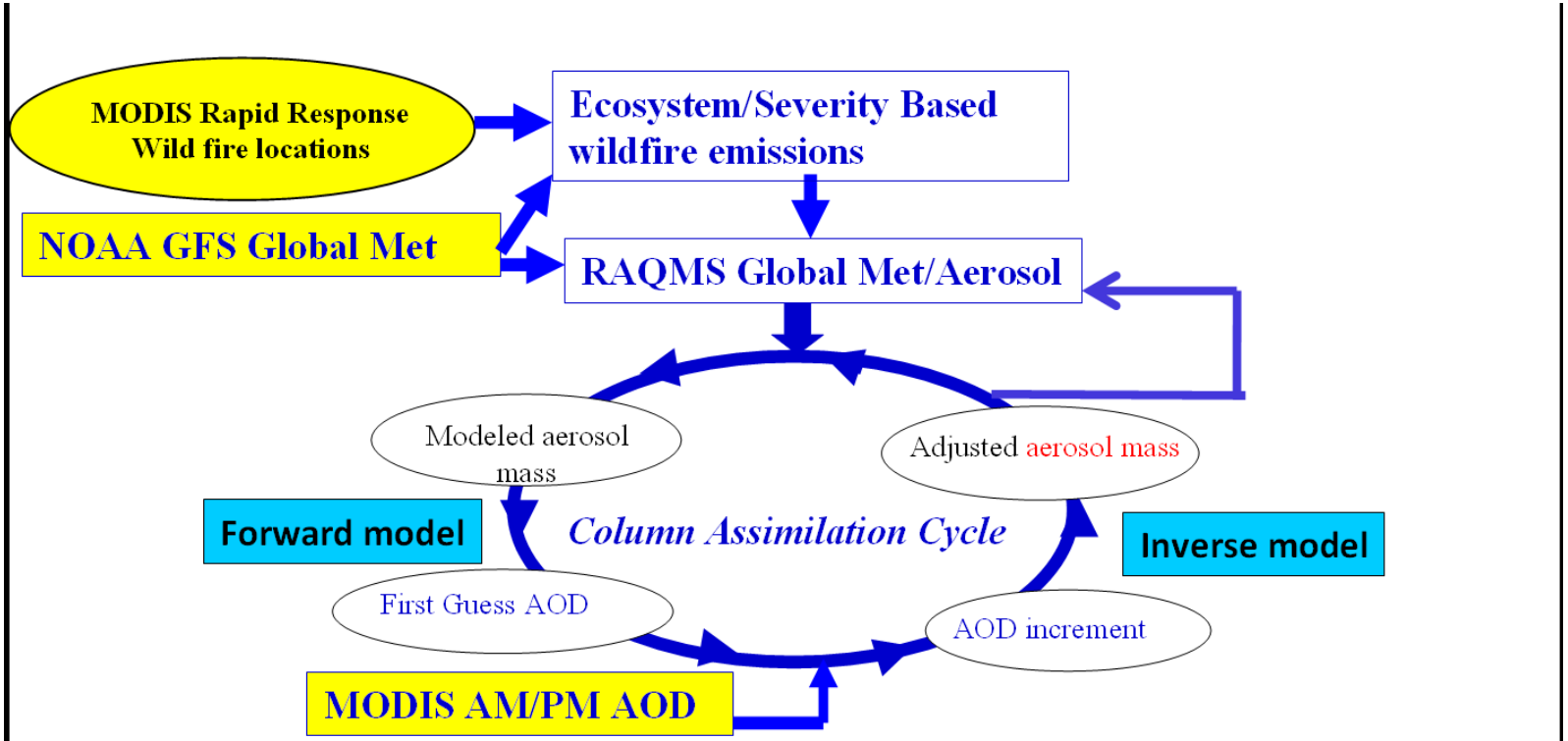
# Comparison with NOAA P3 Insitu O3 Measurements (Primarily LA Basin/Central Valley)




Assimilation of MLS+OMI O3 retrievals results in increased lower-tropospheric O3 (and improved agreement with airborne insitu O3) over Southern California



# RAQMS CalNex AOD Assimilation Procedure



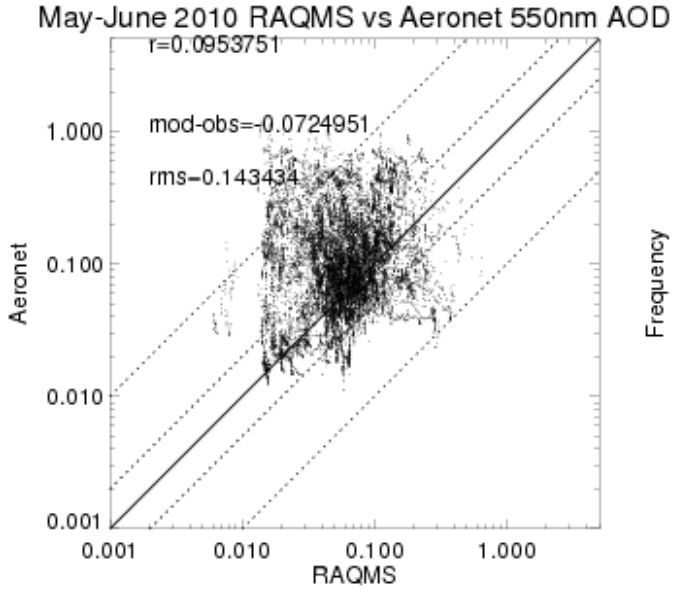

**Forward model:**
Compute layer/species extinction based on tabulated extinction efficiency and hydroscopic growth factors

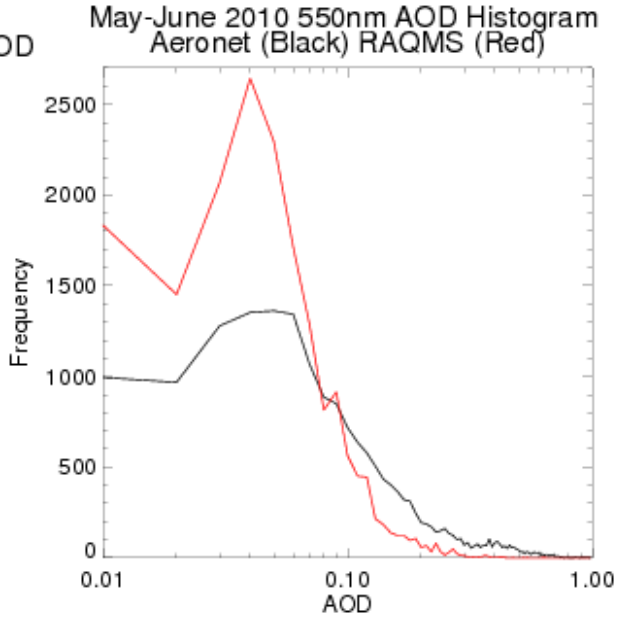
**Inverse model:**
Distribute total AOD increment across aerosol dry mass based on layer/species extinction accounting for extinction due to hydroscopic growth

**Demonstration of:**

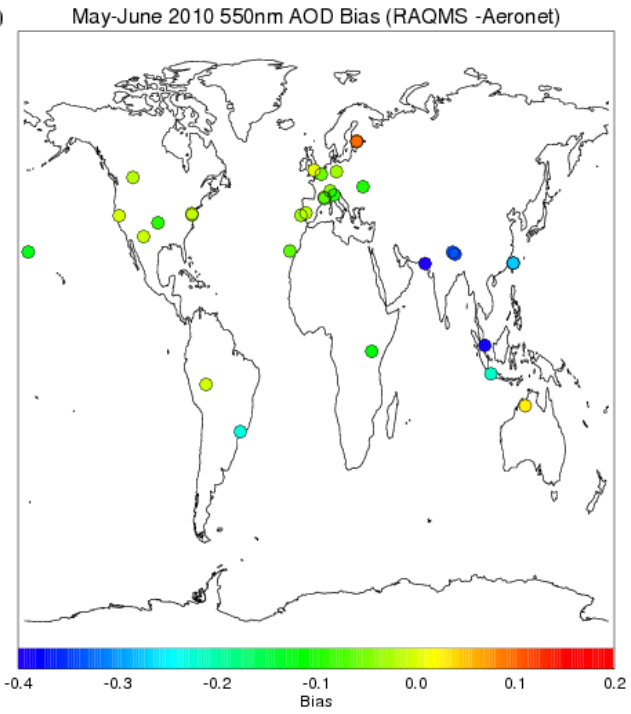
- Real-time assimilation of MODIS Aerosol Optical Depth (AOD)
- Real-time incorporation of MODIS based biomass burning emissions

# Comparison with Level 2.0 Aeronet Measurements



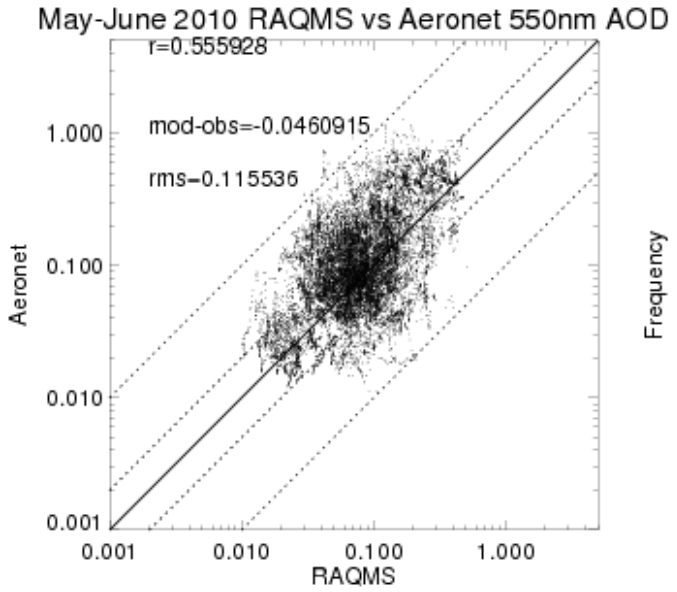

**No MODIS Assimilation**

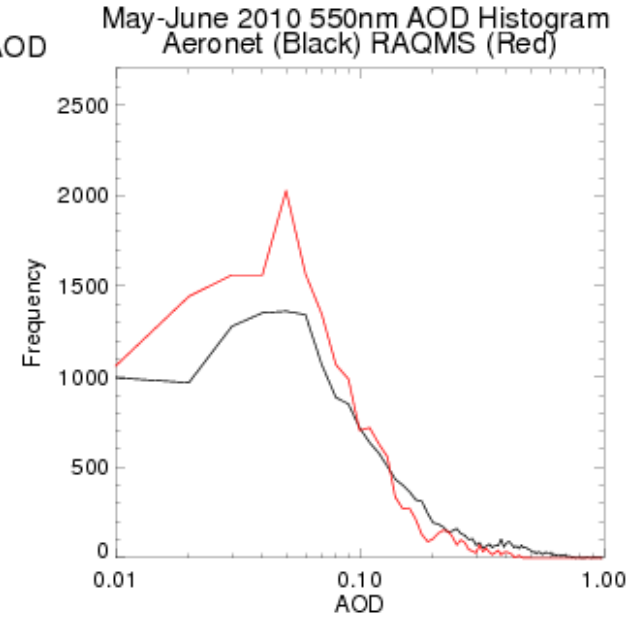



RAQMS (no assim) is not correlated with Aeronet AOD (r=.09) and underestimates clear-sky AOD by 0.07.

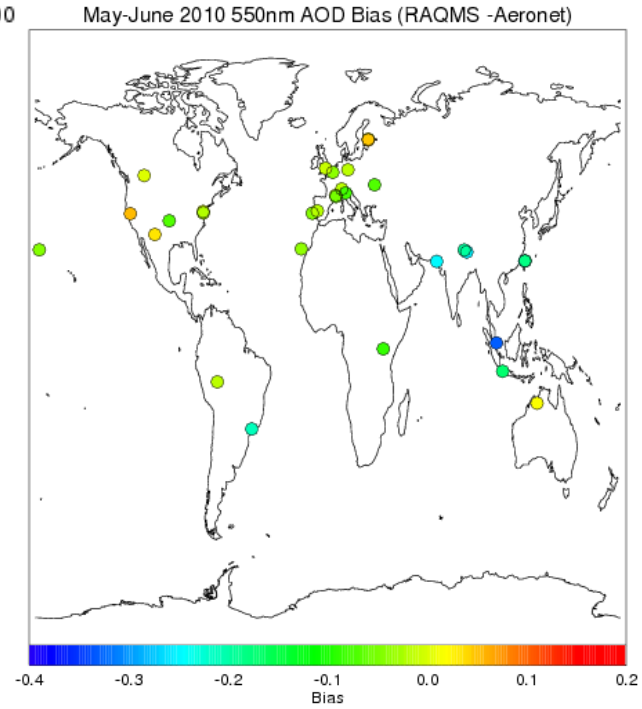
RAQMS (no assim) significantly overestimates the frequency of low AOD (<0.1) and significantly underestimates the frequency of high AOD (>0.1).

# Comparison with Level 2.0 Aeronet Measurements




**MODIS Assimilation**



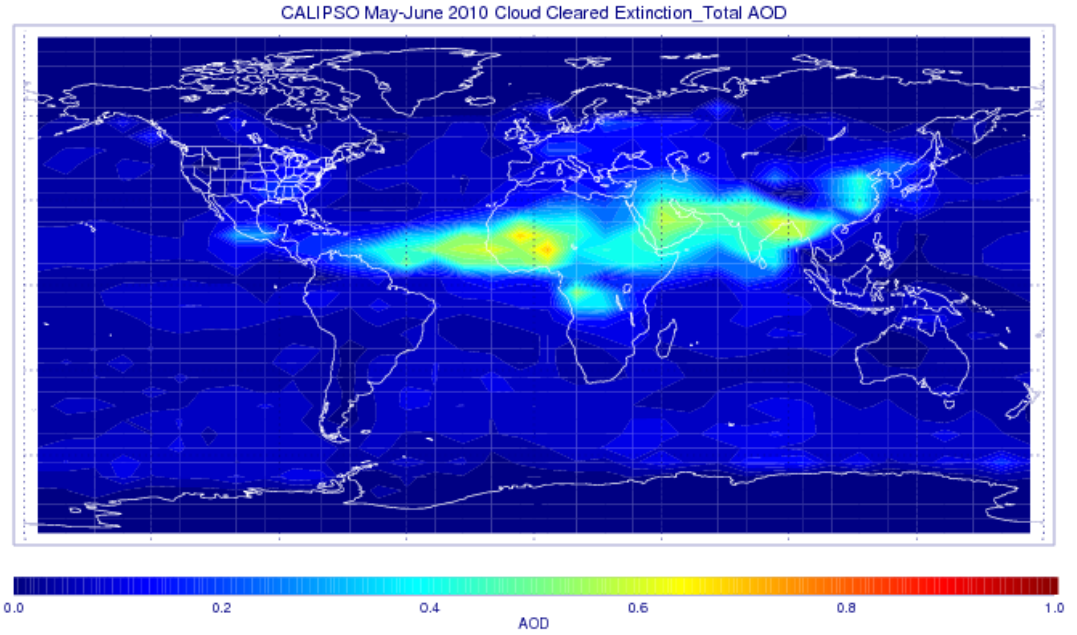

MODIS assimilation significantly improves correlation with Aeronet AOD (r=.56) and reduces the overestimates the frequency of low AOD (<0.1) and underestimates the frequency of high AOD (>0.1).

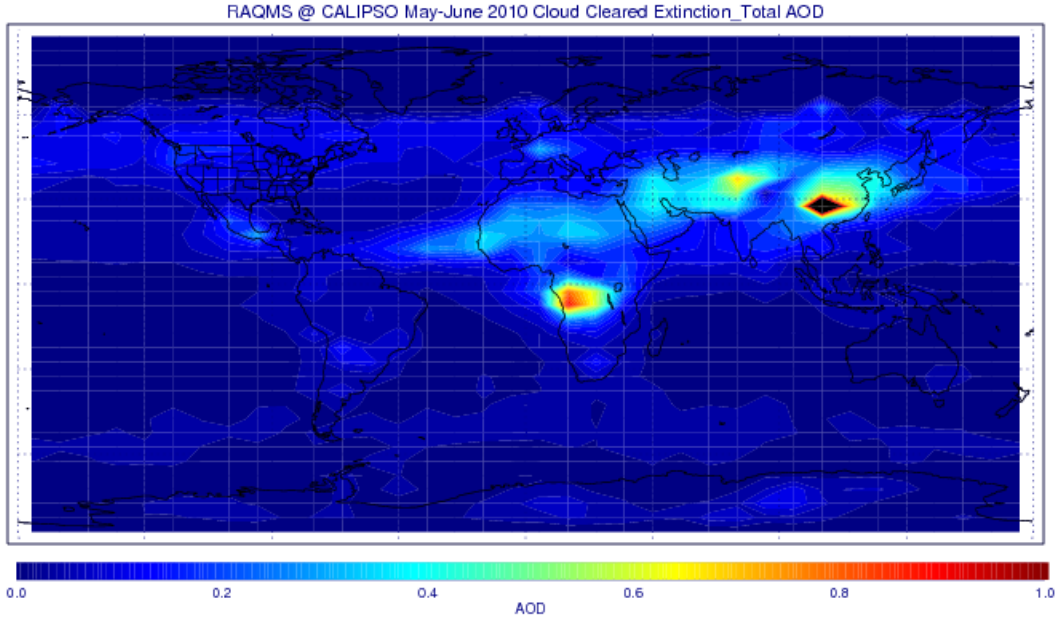
# CALIPSO and Co-located RAQMS AOD May-June 2010

V3-01 aerosol profile retrievals
5º Lat, 10º Lon, 1km bins
CAD< -20, COT=0.0
QC=0,1 (unadjusted retrievals)

Clear sky CALIPSO scenes are dominated by Saharan Dust and South Asian emissions during May-June 2010

RAQMS underestimates Saharan Dust and overestimates SE Asian and S African AOD relative to CALIPSO during May-June 2010



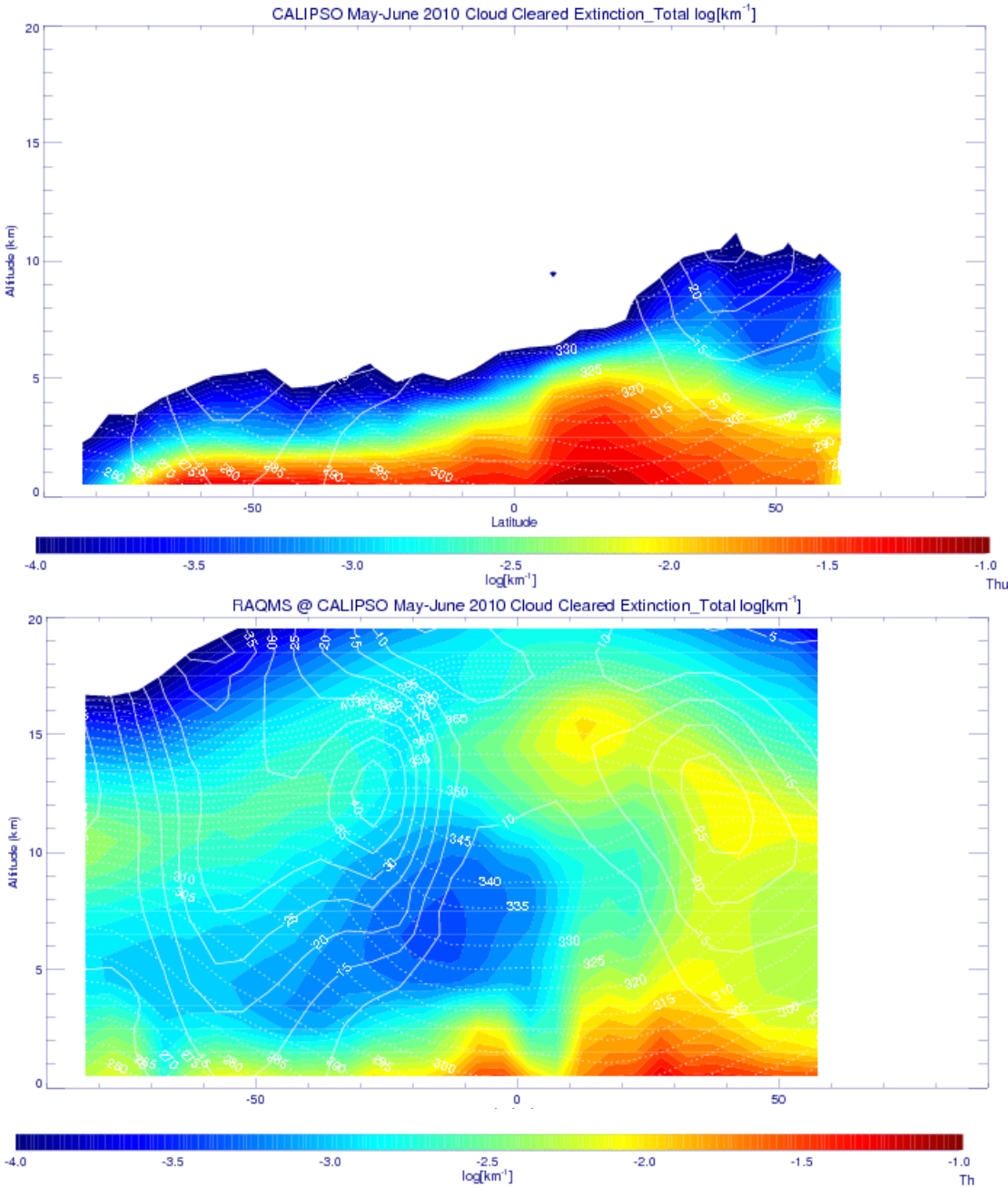
# CALIPSO and Co-located RAQMS Extinction May-June 2010

V3-01 aerosol profile retrievals
5º Lat, 10º Lon, 1km bins
CAD< -20, COT=0.0
QC=0,1 (unadjusted retrievals)

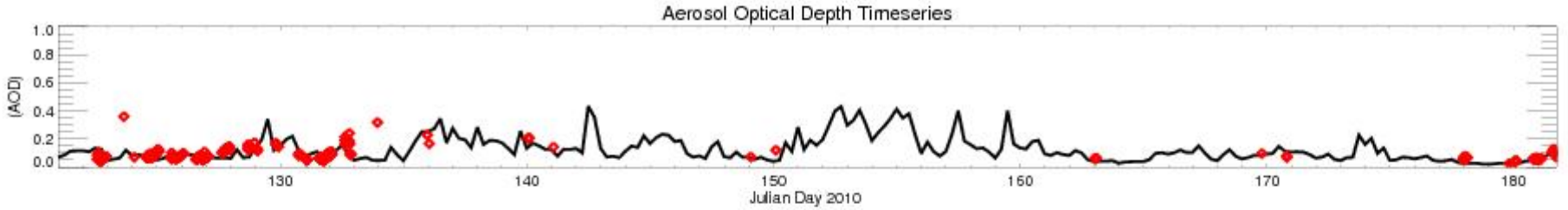
RAQMS underestimates clear-sky extinction below 5km and overestimates clear-sky extinction above 5km relative to CALIPSO.

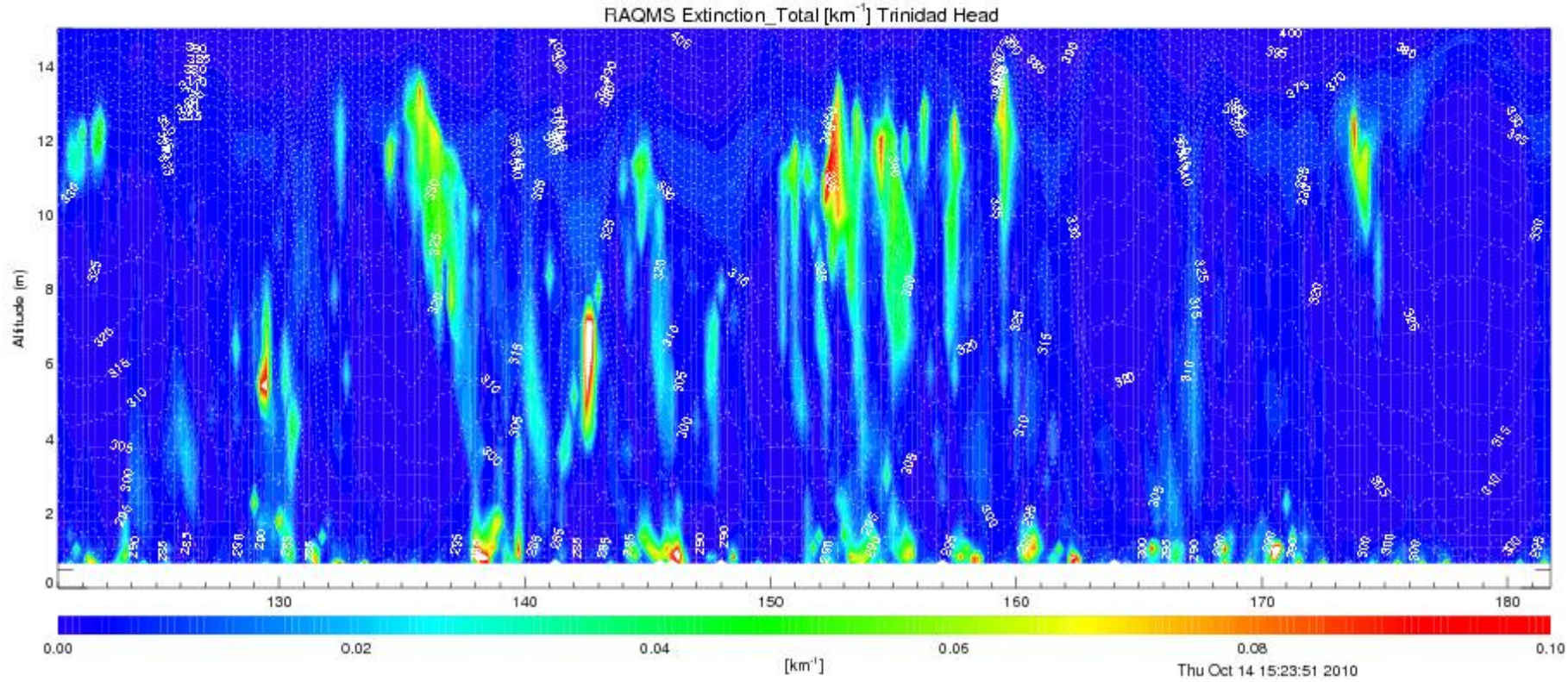
Note: CALIPSO limit of detection is ~0.01 /km*, which is above the majority of the RAQMS upper tropospheric extinction values.

*varies somewhat with lighting conditions, altitude and aerosol type.



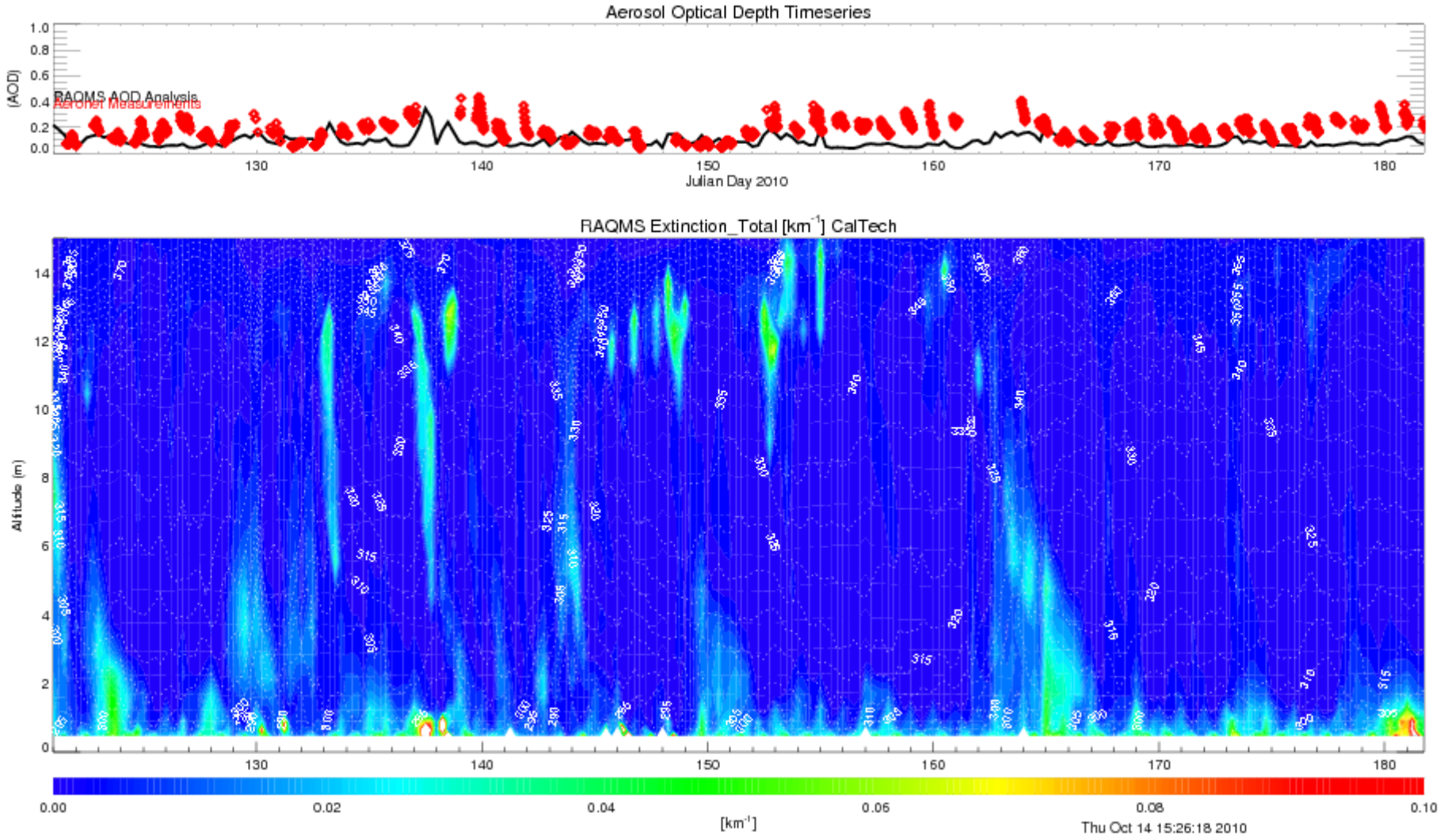
# Comparison with Level 1.5 Aeronet Measurements Trinidad Head (Remote site, PI Ellsworth G. Dutton)



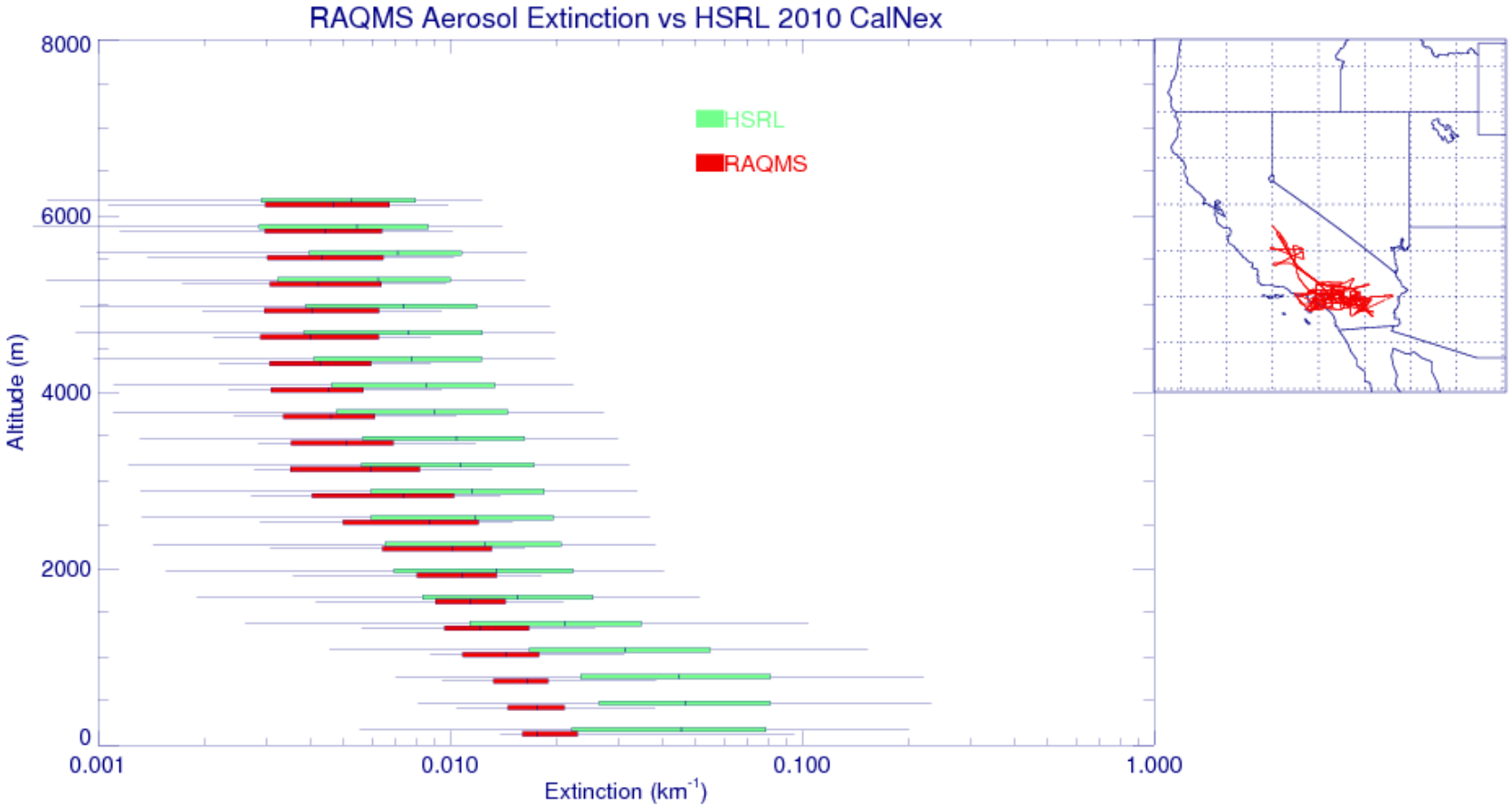

RAQMS Total AOD is in good agreement with Aeronet at Trinidad Head (Remote Site)
Periods of high AOD are associated lofted black and organic carbon aerosol extinction

# Comparison with Level 1.5 Aeronet Measurements CalTech (LA Basin site, PI Jochen Stutz )




RAQMS Total AOD is low relative to Aeronet at CalTech (LA basin site)

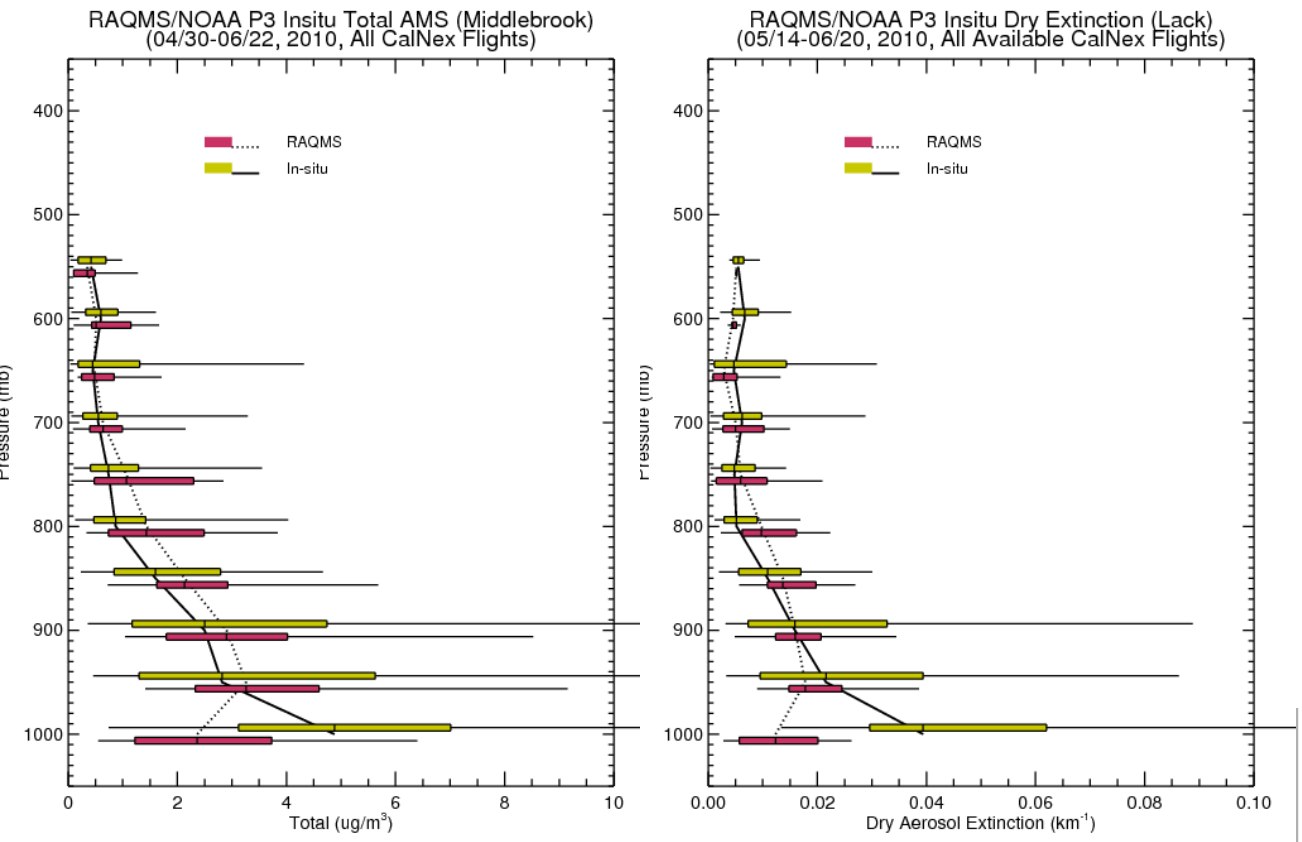
# Comparison with HSRL Lidar Measurements (Primarily LA Basin)




RAQMS underestimates aerosol extinction by 50-100% relative to HSRL.

Largest biases are found within the LA Basin Boundary Layer (below 1000m) were RAQMS median extinction is <0.02 $km^{-1}$ and HSRL median extinction is >0.04$km^{-1}$

# Comparison with NOAA P3 Insitu Aerosol Measurements (Primarily LA Basin/Central Valley)





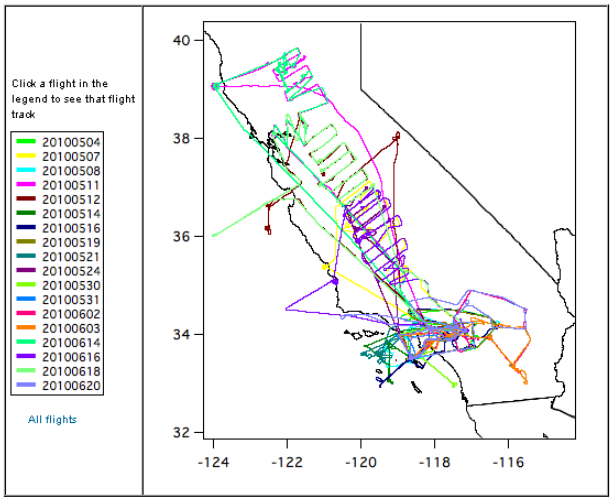


RAQMS shows good agreement in median aerosol mass and dry extinction values above 950mb.

RAQMS underestimates median aerosol mass and dry extinction below 950mb.

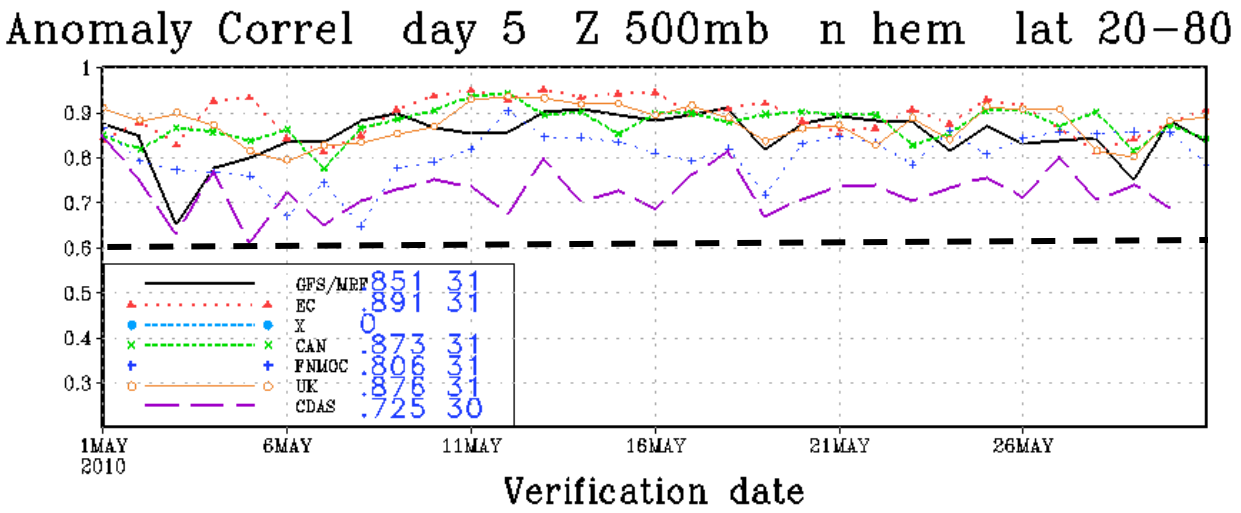
<u>P3 comparisons suggest that:</u>

- Boundary Layer ambient extinction differences arise due to underestimates in local LA sources and neglect of nitrate aerosol in GOCART module
- Free tropospheric ambient extinction differences arise due to underestimates in hydroscopic growth of aerosols



# Assessment of Global 850mb O3 and Aerosol Extinction Forecast Skill

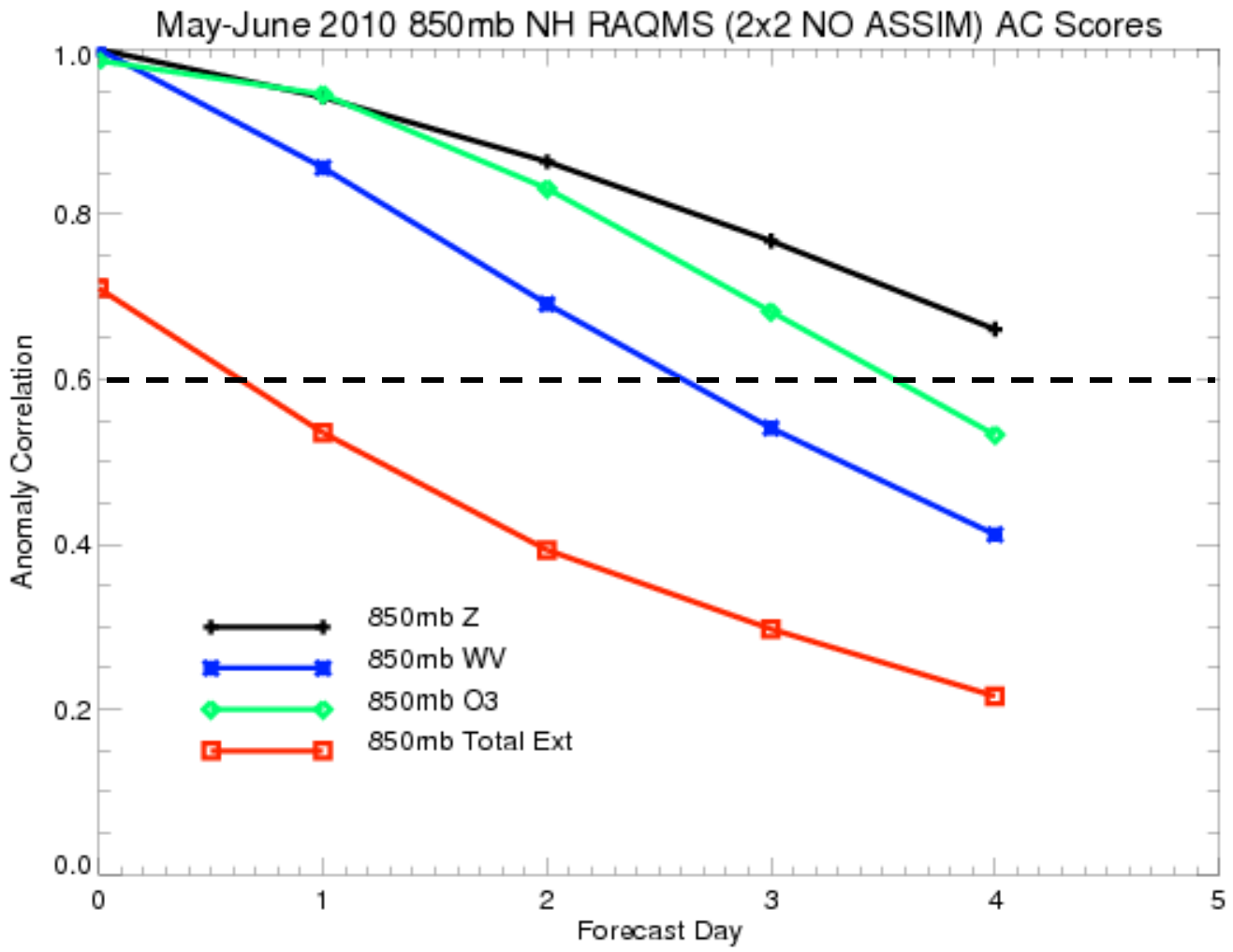
- Anomaly Correlations (AC)
  - Correlation between forecast and analysis
  - May-June mean removed
  - Spectrally truncated to wavenumber 20
  - Averaged from 20N-80N




**useful Skill**

http://www.emc.ncep.noaa.gov/gmb/STATS/html/monarch.html

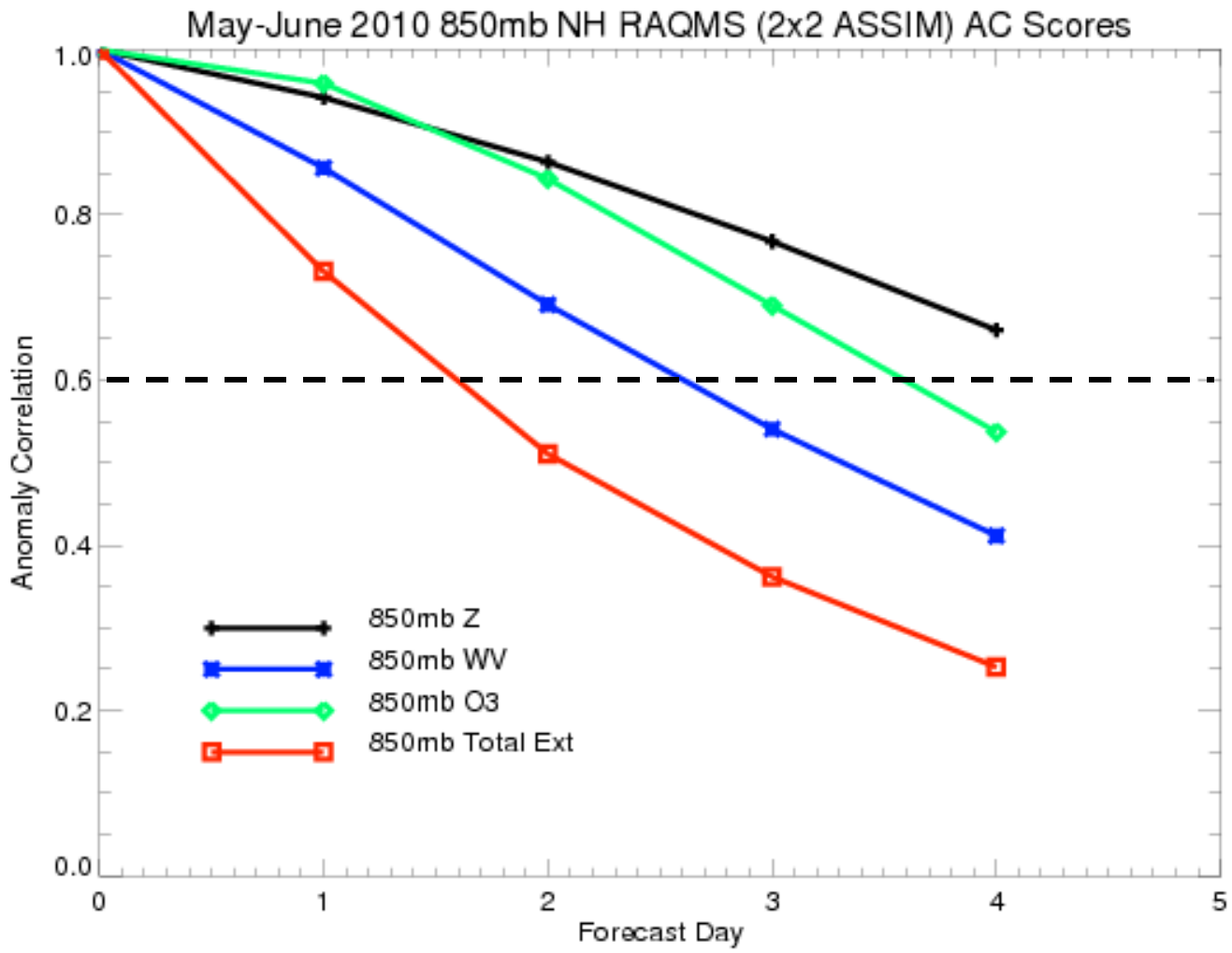
# Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (No Assimilation)




**useful Skill**

- 850mb ozone forecasts have useful skill past 3 days (significantly better than water vapor)
- 850mb extinction forecasts do not have useful skill at 1 day

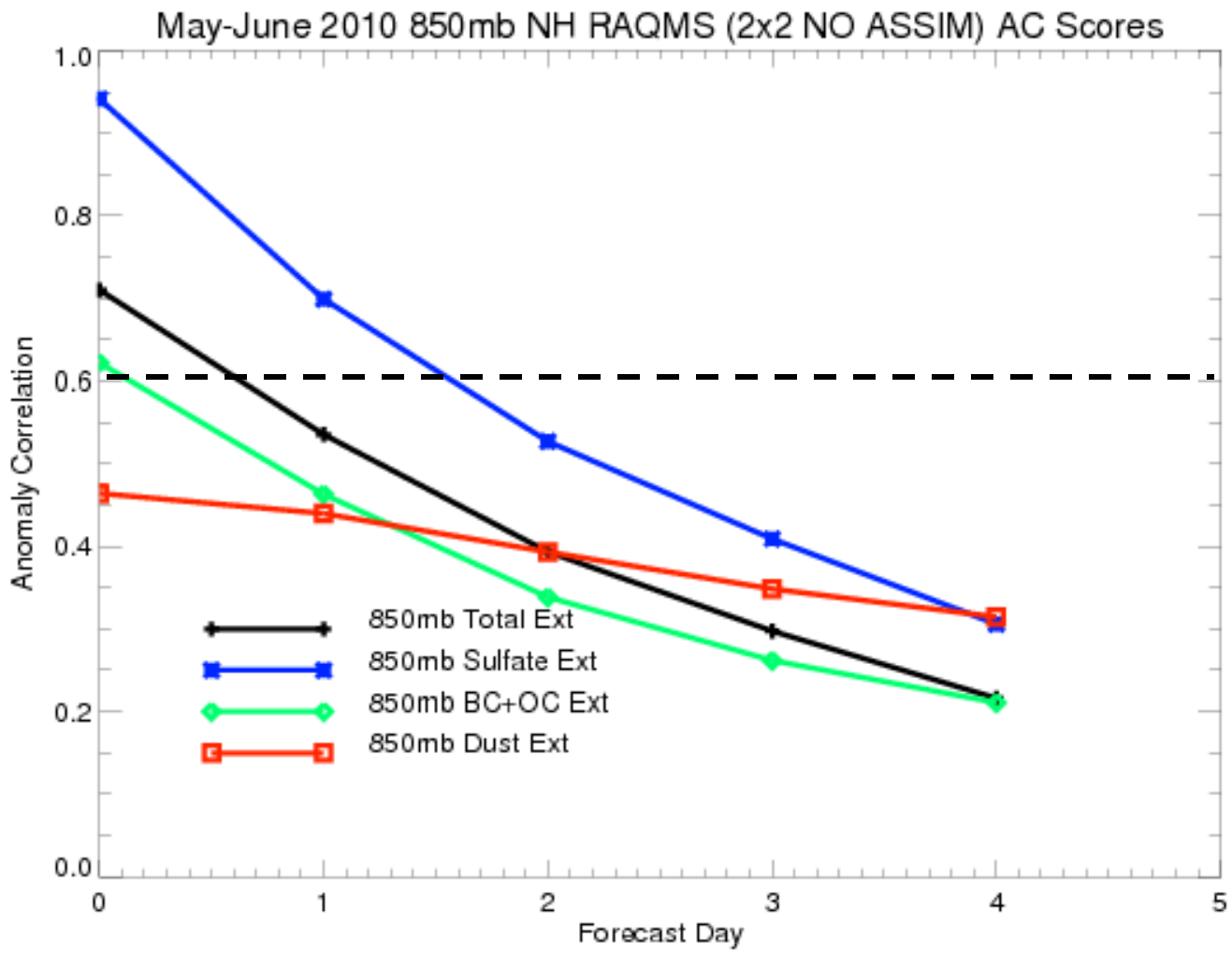
# Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (With MLS/OMI/MODIS Assimilation)




**useful Skill**

- Assimilation of O3 retrievals results in slight improvements in 850mb ozone forecasts
- Assimilation of AOD retrievals results in significant improvement in 850mb extinction forecasts with useful skill at ~1.5 days

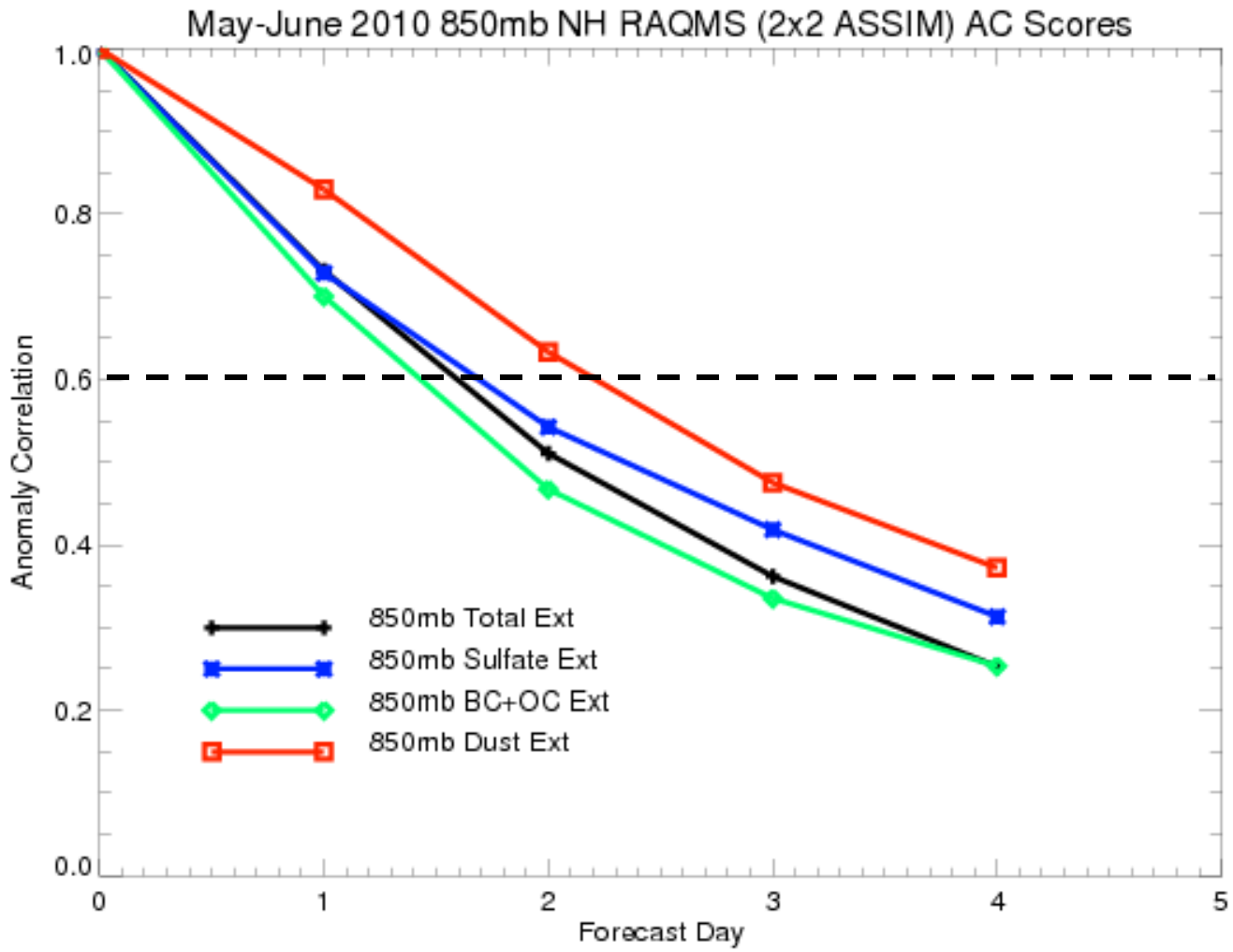
# Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (No Assimilation)




**useful Skill**

- Only 850mb SO4 extinction forecasts useful skill past 1 day
- Black and organic carbon (BC+OC) and dust extinctions are both poorly initialized and forecasted

# Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) (With MODIS Assimilation)




**useful Skill**

- MODIS AOD assimilation results in small changes in 850mb SO4 extinction forecasts
- MODIS AOD assimilation results in significant improvements in black and organic carbon (BC+OC) and dust forecast skill (dust prediction useful at 2 days)

# Conclusions

***RAQMS CalNex ozone assimilation experiments show that assimilation of real-time MLS and OMI ozone retrievals results in significant increases in lower stratospheric ozone.***

- Strat/Trop exchange leads to increased upper and middle tropospheric ozone mixing ratios and improves agreement with ozonesonde measurements
- Assimilation also leads to increased lower-tropospheric O3 (and improved agreement with airborne insitu O3) over Southern California

***RAQMS CalNex aerosol assimilation experiments show that assimilation of real-time Terra and Aqua MODIS AOD retrievals results in significant improvements in large scale aerosol analyses***

- Comparisons with airborne insitu measurements of aerosol dry mass and extinction show that underestimates in aerosol extinction during CalNex arise from two factors:

    1. Boundary Layer ambient extinction differences arise due to underestimates in local LA sources and neglect of nitrate aerosol in GOCART module
    2. Free tropospheric ambient extinction differences arise due to underestimates in hydroscopic growth of aerosols

***RAQMS O3 and Aerosol forecast experiments show, based on large-scale Anomaly Correlation statistics, that***

- Assimilation of O3 retrievals results in slight improvements in 850mb ozone forecasts
- Assimilation of AOD retrievals results in significant improvements in black and organic carbon (BC+OC) and dust forecast skill